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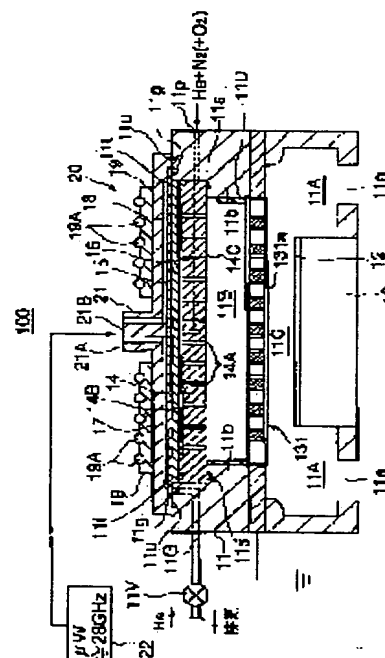
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(54) PROCESS AND APPARATUS FOR SUBSTRATE TREATMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a process and an apparatus for plasma substrate treatment which enable substrate treatment using atomic nitrogen N*.

SOLUTION: In a treatment vessel, a plasma excitation region and a process region are formed by a control electrode. Using He as a plasma excitation gas in the plasma region, N₂ gas is excited in He plasma to form atomic nitrogen N*. The atomic nitrogen N* is allowed to diffuse through the control electrode into the process region to perform substrate treatment.



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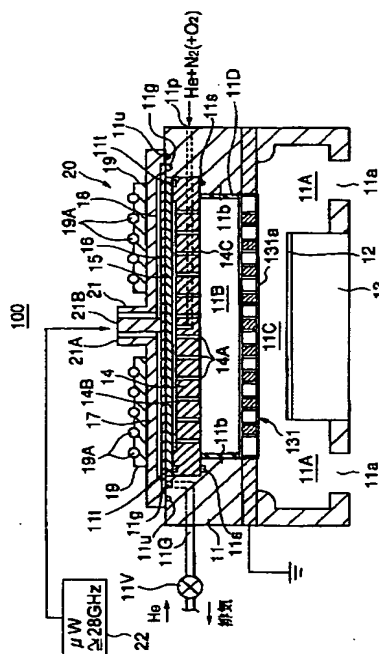
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(54)【発明の名称】 基板処理方法および基板処理装置

(57)【要約】

【課題】 原子状窒素N*を使った基板処理が可能なプラズマ基板処理方法および装置を提供する。

【解決手段】 処理容器中に制御電極によりプラズマ励起空間とプロセス空間とを画成し、プラズマ空間においてHeをプラズマ励起ガスとして使い、Heプラズマ中においてN₂ガスを励起して原子状窒素N*を形成する。かかる原子状窒素N*を制御電極を通してプロセス空間に拡散させ、基板処理を行う。



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CLAIMS

[Claim(s)]

[Claim 1] It is a substrate art by the substrate processor of a configuration of that the process space which contains a processed substrate in a processing container, and the plasma formation space where said processed substrate is not contained are separated with the control electrode. The process which supplies the gas containing helium and N₂ into said processing container, and the process which forms the plasma in said plasma formation space on conditions by which atom-like nitrogen N* is excited in said plasma, The substrate processor according to claim 1 characterized by the process which nitrides a processed substrate front face by said atom-like nitrogen N*.

[Claim 2] The process which excites said plasma is a substrate art according to claim 1 or 2 characterized by performing so that 23-25eV medium excitation state energy may be realized.

[Claim 3] The process which forms said plasma is a substrate art according to claim 1 or 2 characterized by including the process which supplies microwave to said plasma formation space.

[Claim 4] The process which supplies said microwave is a substrate art given [among claims 1-3 characterized by performing by driving a radial line slot antenna] in any 1 term.

[Claim 5] The process which forms said plasma is a substrate art according to claim 1 or 2 characterized by including the process which forms induction field in said plasma formation space.

[Claim 6] The process which forms said induction field is a substrate processor according to claim 5 characterized by including the process which drives the induction coil wound around said perimeter of a processing container with high-frequency power.

[Claim 7] It is a substrate processor given [among claims 1-6 characterized by grounding said control electrode at the process which excites said plasma] in any 1 term.

[Claim 8] A substrate processor given [among claims 1-6 characterized by impressing negative potential to said control electrode at the process which forms said plasma] in any 1 term.

[Claim 9] The gas supplied into said processing container is a substrate processor given [among claims 1-8 characterized by including O₂ further] in any 1 term.

[Claim 10] The processing container equipped with the maintenance base which is formed with an outer wall and holds a processed substrate, The exhaust air system combined with said processing container, and the plasma gas feed zone which supplies plasma excitation gas and raw gas into said processing container, Between the micro aperture which met said processed substrate and was prepared on said processing container, and the processed substrate on said maintenance base and

said plasma gas feed zone It is prepared so that said processed substrate may be met, and it consists of a control electrode which separates the plasma excitation space containing said microwave aperture, and the process space containing said processed substrate. Said control electrode the conductor which has two or more openings which pass the plasma formed in said processing container -- the substrate processor characterized by consisting of a member and covering said control-electrode front face with the aluminum oxide or the conductive nitride.

[Claim 11] Said control electrode is a substrate processor according to claim 10 which has a grid configuration and is characterized by being grounded.

[Claim 12] It is the substrate processor according to claim 10 which said control electrode has a grid configuration and is characterized by said substrate processor including the negative voltage source connected to said control electrode.

[Claim 13] It is a substrate processor given [among claims 10-12 characterized by covering the wall of said processing container with the insulating layer in said plasma excitation space] in any 1 term.

[Claim 14] A substrate processor given [among claims 10-13 characterized by furthermore having the microwave antenna combined with said microwave aperture on the outside of said processing container] in any 1 term.

[Claim 15] The processing container equipped with the maintenance base which is formed with a quartz-glass wall and holds a processed substrate, The exhaust air system combined with said processing container, and the plasma gas feed zone which supplies plasma excitation gas and raw gas into said processing container, The control electrode which is prepared so that the processed substrate on said maintenance base may be met, and divides said interior of a processing container into the process space containing said processed substrate, and plasma excitation space, It consists of an induction coil prepared in said quartz-glass wall outside corresponding to said plasma excitation space. Said control electrode the conductor which has two or more openings which pass the plasma formed in said processing container -- the substrate processor characterized by consisting of a member and covering said control-electrode front face with the aluminum oxide or the conductive nitride.

[Claim 16] Said said quartz-glass wall is a substrate processor according to claim 15 characterized by forming dome up space.

[Claim 17] Said control electrode is a substrate processor according to claim 15 or 16 characterized by being grounded.

[Claim 18] Said control electrode is a substrate processor according to claim 15 or 16 characterized by connecting with a negative voltage source.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] Generally this invention relates to plasma treatment equipment, especially relates to microwave plasma treatment equipment.

[0002] A plasma treatment process and plasma treatment equipment are close to 0.1 micrometers called the so-called deep submicron component in recent years or a deep subquarter micron component, or are the overly indispensable technique for manufacture of a detailed-ized semiconductor device, and manufacture of the high resolution flat-surface display containing a liquid crystal display of having the gate length not more than it.

[0003] Although the excitation method of more various plasma than before is used as plasma treatment equipment used for manufacture of a semiconductor device or a liquid crystal display, parallel plate mold high-frequency excitation plasma treatment equipment or inductive-coupling mold plasma treatment equipment is especially common. However, the plasma formation of plasma treatment equipment of these former is uneven, and since the field where electron density is high is limited, performing a uniform process over the whole processed substrate surface, big processing speed, i.e., throughput, has the difficult trouble. Especially this problem becomes serious when processing the substrate of a major diameter. And with the plasma treatment equipment of these former, since electron temperature is high, a damage arises in the semiconductor device formed on a processed substrate, and that the metal contamination by sputtering of a processing interior wall is large etc. has some essential problems. For this reason, it is becoming difficult to fill the severe demand to the further detailed-izing of a semiconductor device or a flat-surface display and improvement in the further productivity with conventional plasma treatment equipment.

[0004] The microwave plasma treatment equipment using the high density plasma excited by microwave electric field on the other hand, without using a direct-current magnetic field conventionally is proposed. For example, microwave is emitted in a processing container from the plane antenna (radial line slot antenna) which has the slot of a large number arranged so that uniform microwave might be generated, and the plasma treatment equipment of a configuration of ionizing the gas in a vacuum housing by this microwave electric field, and exciting the plasma is proposed. For example, refer to the JP,9-63793,A official report. It is possible to be able to realize a high plasma consistency over the large field directly under an antenna with the microwave plasma excited by such technique, and to perform uniform plasma treatment for a short time. And with the microwave plasma formed by this technique, in order to excite the plasma by microwave, electron temperature is low, and damage metallurgy group contamination of a processed substrate can be avoided. Since the still more uniform plasma also on a large area substrate can be excited easily, it can

respond also to the production process of a semiconductor device and the manufacture of a large-scale flat-surface display using the diameter semi-conductor substrate of macrostomia easily.

[0005]

[Description of the Prior Art] Drawing 1 shows the rough configuration of conventional inductive-coupling mold plasma treatment equipment 1.

[0006] With reference to drawing 1, plasma treatment equipment 1 is equipped with the processing container 2 which consists of a quartz dome exhausted by exhaust air line 2A, and the processed substrate 4 is held on the substrate maintenance base 3 which rotates by rotation device 3A in process space 2B formed with said processing container 2. Furthermore, raw gas, such as inactive plasma excitation gas, such as Ar, oxygen, or nitrogen, is supplied to said process space 2B by raw gas supply line 2C. Moreover, the coil 5 is wound around the outside upper part of said processing container 2, and high density plasma 2D is excited by the upper part of said process space 2B by driving said coil 5 by DC power supply.

[0007] With the plasma treatment equipment 1 of drawing 1, the radical of the raw gas formed in connection with this high density plasma 2D arrives at the front face of the processed substrate 4, and substrate processing of oxidation, nitriding, etc. is performed.

[0008] However, with such conventional inductive-coupling mold plasma treatment equipment 1, concentration distribution of the radical which the field in which high density plasma 2D is formed is carrying out localization to the upper part of the processing container 2, therefore is formed in connection with the plasma becomes a remarkable uneven thing. Especially the ununiformity of the radical concentration to the direction of a path of a substrate is not canceled even if it rotates the substrate maintenance base 3 by rotation device 3A.

[0009] For this reason, although the distance between the processed substrate 4 and the formation field of high density plasma 2D was detached with conventional inductive-coupling mold plasma treatment equipment 1 in order to realize the most uniform possible radical concentration distribution in said processed substrate 4 front face consequently, the problem whose amount of radicals which reaches the processed gas 4 the magnitude of the substrate processor 1 whole becomes large, or decreases had arisen. This problem becomes serious when it is going to process the diameter substrate of macrostomia especially in accordance with the flow of the latest technique.

[0010] The microwave plasma treatment equipment using the high density plasma excited by microwave electric field on the other hand, without using an induction magnetic field conventionally is proposed. For example, microwave is emitted in a processing container from the plane antenna (radial line slot antenna) which has the slot of a large number arranged so that uniform microwave might be generated, and the plasma treatment equipment of a configuration of ionizing the gas in a vacuum housing by this microwave electric field, and exciting the plasma is proposed. For example, refer to the JP,9-63793,A official report. It is possible to be able to realize a high plasma consistency over the large field directly under an antenna with the microwave plasma excited by such technique, and to perform uniform plasma treatment for a short time. And with the microwave plasma formed by this technique, in order to excite the plasma by microwave, electron temperature is low, and damage metallurgy group contamination of a processed substrate can be avoided. Since the still more uniform plasma also on a large area substrate can be excited easily, it can respond also to the production process of a semiconductor device and the manufacture of a large-scale flat-surface display using the diameter semi-conductor substrate of macrostomia easily.

[0011] Drawing 2 shows the configuration of the microwave plasma treatment equipment 10 using this radial line slot antenna which the artificer of this invention proposed previously.

[0012] With reference to drawing 2, microwave plasma treatment equipment 10 has the processing room 11 exhausted from two or more exhaust port 11a, and the maintenance base 13 holding the processed substrate 12 is formed all over said processing room 11. Since uniform exhaust air of said processing room 11 is realized, space 11A is formed in the perimeter of said maintenance base 13 in the shape of a ring, it is regular intervals like, namely, said processing room 11 can be exhausted to homogeneity through said space 11A and exhaust port 11a by [which open said two or more exhaust port 11a for free passage to said space 11A] forming in axial symmetry to a processed substrate.

[0013] On said processing room 11, in the location which meets the processed substrate 12 on said maintenance base 13 as some outer walls of said processing room 11 It is formed through the seal ring which the tabular shower plate 14 which it consisted [plate] of low loss dielectrics, such as aluminum 2O3 and SiO2, and had much opening 14A formed does not illustrate. aluminum 2O3 is formed through another seal ring which the cover plate 15 which consists of low loss dielectrics, such as SiO2, does not illustrate still as well as the outside of said shower plate 14.

[0014] Gas-passageway 14B is formed in the top face at said shower plate 14, and each of two or more of said opening 14A is formed so that it may be open for free passage to said gas-passageway 14B. furthermore, inside said shower plate 14 Gas supply path 14C which is open for free passage to gas supply port 11p prepared in the outer wall of said processing container 11 is formed. The plasma excitation gas supplied to said gas supply port 11p, such as Ar and Kr Said opening 14A is supplied through said supply path 14C to said path 14B, and it is substantially emitted to process space 11B of said shower plate 14 directly under of said processing container 11 interior by uniform concentration from said opening 14A.

[0015] On said processing container 11, further, it estranges 4-5mm from said cover plate 15, and the radial line slot antenna 20 is formed on the outside of said cover plate 15. It connects with the external source of microwave (not shown) through the coaxial waveguide 21, and said radial line slot antenna 20 excites the plasma excitation gas emitted to said process space 11B by the microwave from said source of microwave. It is stuck between said cover plate 15 and the radial plane of the radial line slot antenna 20, and the cooling block 19 which has cooling water path 19A is further established on said antenna 20 for cooling of an antenna.

[0016] Said radial line slot antenna 20 consists of flat disk-like body 17 of an antenna connected to outside waveguide 21A of said coaxial waveguide 21, and a radiation plate 16 which was formed in opening of said body 17 of an antenna and which had many slots formed, and the late phase plate 18 with which thickness consists of a fixed dielectric plate is inserted between said bodies 17 of an antenna and said radiation plates 16.

[0017] In the radial line slot antenna 20 of this configuration, although the microwave to which electric power was supplied from said coaxial waveguide 21 advances radially between the body 17 of an antenna of the shape of said disk, and the radiation plates 16 with breadth, wavelength is compressed by operation of said late phase plate 18 in that case. then, the wavelength of the microwave which does in this way and advances radially -- corresponding -- said slot -- concentric circular -- and the plane wave which has a circularly-polarized wave can be substantially emitted in the vertical direction by forming so that it may intersect perpendicularly mutually at said radiation plate 16.

[0018] The uniform high density plasma is formed in process space 11B of said

shower plate 14 directly under by using this radial line slot antenna 20. Thus, the metal contamination which electron temperature is low, therefore a damage does not arise in the processed substrate 12, and originates in sputtering of the container wall of the processing container 11 does not produce the formed high density plasma.

[0019] Then, by supplying the mixed gas of O₂ gas, NH₃ gas or N₂ gas, and H₂ gas other than plasma excitation gas, such as Ar and Kr, to said gas installation port 11p as raw gas in the substrate processor 10 of drawing 2 It becomes possible by active species', such as atom-like oxygen O*^s or nitriding hydrogen radical NH*^s, being excited by said high density plasma, and using this active species into said process space 11B, oxidation treatment, nitriding treatment, or to carry out acid nitriding treatment about processed substrate 12 front face.

[0020] Moreover, 7<7< 6-///&N0001=11&N0552=9&N0553=000005" As

shown in TARGET="tjitemdrw"> drawing 3, it sets to the substrate processor 10 of drawing 2. Raw gas path 31A which is open for free passage in the lower part of said shower plate 14 at raw gas installation port 11r formed in processing container 1 front face, Substrate processor 10A of a configuration of having formed another lower-berth shower plate 31 which has big opening which passes the raw gas radical which was equipped with raw gas installation nozzle opening 31B of a large number which are open for free passage to said raw gas path 31A, and was formed in said space 11B is proposed.

[0021] It becomes possible to prevent that microwave invades into process space 11C by another process space 11C's being formed by the lower part of said lower-berth shower plate 31, and constituting especially the lower-berth shower plate 31 from substrate processor 10A of drawing 3 with conductors, such as a stainless steel by which passive state processing of the front face was carried out with the aluminum oxide (aluminum 2O₃). Then, it is limited to space 11B of upper case shower plate 14 directly under, and radical K* or Ar* of Kr or Ar excited in said space 11B passes big opening in said shower plate 31 to said process space 11C, and invades into it, and excitation of the plasma activates the raw gas emitted from said nozzle opening 31B. Processing of the processed substrate 12 is made by the raw gas radical activated by doing in this way.

[0022] In substrate processor 10A of drawing 3, by constituting said lower-berth shower plate 31 with a conductor, microwave is eliminated from said process space 11C, and breakage by the microwave of a processed substrate is avoided.

[0023] In substrate processor 10A of drawing 3, it is possible by introducing CVD material gas from said lower-berth shower plate 31 to perform a plasma-CVD process. Moreover, it is also possible by introducing dry etching gas and impressing high frequency bias to said maintenance base 13 from said lower-berth shower plate 31, to perform a dry etching process.

[0024]

[Problem(s) to be Solved by the Invention] Thus, in drawing 2 or the substrate processor of drawing 3, in performing oxidation treatment, it excites Kr radical (Kr*) of the medium excitation state of about 10eV energy by introducing Kr gas and oxygen gas into process space 11B. Excited Kr radical excites atom-like oxygen O* efficiently according to reaction $O_2 \rightarrow O^* + O^*$, and excited atom-like oxygen O* oxidizes the front face of the processed substrate 12.

[0025] On the other hand, in performing nitriding treatment of the processed substrate 12, it introduces Kr gas, ammonia gas or Kr gas, nitrogen gas, and hydrogen gas. In this case, nitriding hydrogen radical NH* is excited by excited Kr radical (Kr*) or Ar radical (Ar*) according to reaction $NH_3 \rightarrow NH^* + 2H^* + e^-$ or reaction $N_2 + H_2 \rightarrow NH^* + NH^*$, and the nitriding treatment of the processed substrate 12 is

made by it using this nitriding hydrogen radical NH^* .

[0026] It may be more desirable for the nitriding reaction force to, use the atom-like nitrogen (N^*) which does not contain hydrogen strongly on the other hand in the case of the nitriding treatment of a processed substrate. Although atom-like nitrogen N^* is formed of reaction $N_2 \rightarrow N^* + N^*$, it is thought that no less than 23–25eV energy is required for it in that case. Since the energy of Kr radical which is obtained in the case of Kr or Ar plasma, or Ar radical is about at most 10eV as stated also in advance, it cannot excite atom-like nitrogen N^* according to the above-mentioned reaction.

[0027] Even if it supplies nitrogen gas with Kr gas or Ar gas in drawing 2 or the substrate processor of drawing 3, reaction $N_2 \rightarrow N_2^{++} + e^-$ will only be obtained and desired atom-like nitrogen N^* will not be excited.

[0028] Drawing 4 shows relation with the excitation energy of the density of states of Kr plasma, atom-like nitrogen N^* , nitriding hydrogen radical NH^* , and nitrogen ion N_2^{++} .

[0029] With reference to drawing 4, while it is large in low energy and energy increases, it turns out that the density of states of Kr plasma decreases quickly. With such plasma, a desired nitrogen radical cannot be excited efficiently.

[0030] Then, let it be a general technical problem for this invention to offer the new and useful substrate processor which solved the above-mentioned technical problem.

[0031] The more concrete technical problem of this invention is to offer the substrate processor which can generate nitrogen radical N^* efficiently.

[0032]

[Means for Solving the Problem] This invention is set in a processing container, as the above-mentioned technical problem was indicated to claim 1. It is a substrate art by the substrate processor of a configuration of that the process space containing a processed substrate and the plasma formation space where said processed substrate is not contained are separated with the control electrode. The process which supplies the gas containing helium and N_2 into said processing container, and the process which forms the plasma in said plasma formation space on conditions by which atom-like nitrogen N^* is excited in said plasma, As the process which nitrides a processed substrate front face by said atom-like nitrogen N^* was indicated to the substrate processor according to claim 1 by which it is characterized, or claim 2, the process which excites said plasma By the substrate art according to claim 1 or 2 characterized by performing so that 23–25eV medium excitation state energy may be realized As indicated to claim 3, or the process which forms said plasma By the substrate art according to claim 1 or 2 characterized by including the process which supplies microwave to said plasma formation space As indicated to claim 4, or the process which supplies said microwave By the substrate art given in any 1 term among claims 1–3 characterized by performing by driving a radial line slot antenna As indicated to claim 5, or the process which forms said plasma By the substrate art according to claim 1 or 2 characterized by including the process which forms induction field in said plasma formation space As indicated to claim 6, or the process which forms said induction field With the substrate processor according to claim 5 characterized by including the process which drives the induction coil wound around said perimeter of a processing container with high-frequency power or as indicated to claim 7, at the process which excites said plasma As indicated to the substrate processor given in any 1 term, or claim 8 among claims 1–6 characterized by grounding said control electrode, at the process which forms said plasma With a substrate processor given in any 1 term among claims 1–6 characterized by impressing negative potential to said control electrode As indicated to claim 9, or the

gas supplied into said processing container With a substrate processor given in any 1 term among claims 1-8 characterized by furthermore including O₂ Or the processing container equipped with the maintenance base which is formed with an outer wall and holds a processed substrate as indicated to claim 10, The exhaust air system combined with said processing container, and the plasma gas feed zone which supplies plasma excitation gas and raw gas into said processing container, Between the micro aperture which met said processed substrate and was prepared on said processing container, and the processed substrate on said maintenance base and said plasma gas feed zone It is prepared so that said processed substrate may be met, and it consists of a control electrode which separates the plasma excitation space containing said microwave aperture, and the process space containing said processed substrate. Said control electrode the conductor which has two or more openings which pass the plasma formed in said processing container -- it consists of a member and said control-electrode front face with the substrate processor characterized by being covered with the aluminum oxide or the conductive nitride As indicated to claim 11, with or the substrate processor according to claim 10 characterized by for said control electrode having a grid configuration and grounding it With or the substrate processor according to claim 10 characterized by for said control electrode having a grid configuration and said substrate processor including the negative voltage source connected to said control electrode as indicated to claim 12 Or as indicated to claim 13, it sets to said plasma excitation space. With a substrate processor given in any 1 term among claims 10-12 characterized by covering the wall of said processing container with ***** With or a substrate processor given in any 1 term among claims 10-13 characterized by having further the microwave antenna combined with said microwave aperture on the outside of said processing container as indicated to claim 14 Or the processing container equipped with the maintenance base which is formed with a quartz-glass wall and holds a processed substrate as indicated to claim 15, The exhaust air system combined with said processing container, and the plasma gas feed zone which supplies plasma excitation gas and raw gas into said processing container, The control electrode which is prepared so that the processed substrate on said maintenance base may be met, and divides said interior of a processing container into the process space containing said processed substrate, and plasma excitation space, It consists of an induction coil prepared in said quartz-glass wall outside corresponding to said plasma excitation space. Said control electrode the conductor which has two or more openings which pass the plasma formed in said processing container -- it consists of a member and said control-electrode front face with the substrate processor characterized by being covered with the aluminum oxide or the conductive nitride As indicated to claim 16, with or the substrate processor according to claim 15 characterized by said said quartz-glass wall forming dome up space As indicated to claim 17, with or the substrate processor according to claim 15 or 16 characterized by grounding said control electrode Or as indicated to claim 18, said control electrode is solved with the substrate processor according to claim 15 or 16 characterized by connecting with a negative voltage source.

[0033]

[Embodiment of the Invention] [1st example] drawing 5 shows the configuration of the substrate processor 100 by the 1st example of this invention. However, the same reference mark is given to the part corresponding to the part explained previously among drawing 5 , and explanation is omitted.

[0034] With reference to drawing 5 , the processing container 11 is equipped with the shower plate 14 through seal 11s, and it is equipped with said cover plate 15 through seal 11t on said shower plate 14. Moreover, it is equipped with said radial line slot

antenna 20 through seal 11u on said processing container 11.

[0035] Furthermore, with the substrate processor 100 of drawing 5, the interface between said radiation plates 16 and cover plates 15 is exhausted through exhaust port 11G which are open for free passage to 11g of circular sulci and this which were formed in the field which engages with said radiation plate of the upper part of said processing container 11, and helium gas of 0.8 atmospheric-pressure extent is further introduced into said interface as a heating medium after that. Introduced helium gas is enclosed with said interface by closing bulb 11V.

[0036] In the substrate processor 100 of drawing 5, the lower shower plate 31 currently used by substrate processor 10A of drawing 3 is removed, and the control electrode 131 which consists of a conductive member of the shape of a grid instead shown in drawing 6 is formed so that said plasma excitation space 11B and process space 11C may be separated.

[0037] The plasma which much openings 132 of the size which the radical excited in plasma excitation space 11B can pass freely are formed in said grid-like control electrode 131 with reference to drawing 6, therefore was excited in said plasma excitation space 11B is freely diffused to process space 11C through said control electrode 131.

[0038] With the configuration of drawing 5, it is reflected by said grid-like control electrode 131 also in the condition that the plasma is not formed in said plasma excitation space 11B, and the microwave which said grid-like control electrode 131 is grounded, consequently was introduced into said plasma excitation space 11B from said radial line slot antenna 20 does not invade into process space 11C. Therefore, the processed substrate 12 does not produce the problem damaged by microwave in the substrate processor 100 of drawing 5.

[0039] Although said grid-like control electrode 131 can be formed by W, Ti, etc., it is possible by forming the conductive nitride, for example, layer 131a of WN or TiN, in the front face to raise the resistance over a plasma exposure. Moreover, this grid-like control electrode 131 may be formed with quartz glass, and conductive nitride layer 131a may be formed in a front face. Furthermore, in the substrate processor 100, the side-attachment-wall side of the processing container 11 is covered by quartz liner 11D in plasma excitation space 11B.

[0040] In the substrate processor 100 of drawing 5, helium gas and N₂ gas are introduced into said raw gas installation port 11p, and about 28GHz microwave is supplied to said radial line slot antenna. Process ** in the processing container 11 is typically set as the range of 66.5–266Pa (0.5 – 2Torr), and the nitriding treatment or acid nitriding treatment of the processed substrate 12 is performed in a 200–500-degree C temperature requirement.

[0041] Drawing 7 shows the density of states of the plasma excited at the time of using helium as plasma gas in the substrate processor 100 of drawing 5.

[0042] With reference to drawing 7, excited helium radical helium* is greatly accelerated by microwave electric field by using helium with a small collision cross-section as plasma gas. Consequently, it turns out that plasma energy increases greatly and sufficient energy to excite atom-like nitrogen N* is acquired. On the other hand, when Kr is being used as plasma gas, it turns out that the excitation efficiency of nitriding hydrogen radical NH* currently excited efficiently or nitrogen ion N₂⁺ is reduced greatly.

[0043] So, in this invention, efficient excitation of atom-like nitrogen N* is realized in 23–25eV high plasma energy by using helium as plasma gas in the substrate processor 100. On the other hand, in order to control that the electron temperature in the plasma becomes high too much, in this invention, about 28GHz or the microwave source of release 22 of the frequency beyond it higher than the microwave proposed

previously is used, and the radial line slot antenna 20 is driven by the microwave generated according to the microwave source of release 22. As a frequency of microwave *****, frequencies, such as about 2.4GHz and 8.3 etc.GHz, may be chosen. By furthermore separating plasma excitation space 11B and process space 11C with a control electrode 131, the electron temperature and plasma energy in process space are reduced to the suitable level for substrate processing.

[0044] As especially explained to the front face of said control electrode 131 previously, when the aluminum₂O₃ passive-state film forms the conductive nitride, a control electrode is effectively protected to the high energy plasma. Moreover, sputtering of processing container 11 wall by the high energy plasma and the problem of contamination of the substrate accompanying this are avoided by covering the wall of the processing container 11 by quartz liner 11D in plasma excitation field 11B.

[0045] Drawing 8 shows the configuration of substrate processor 100A depended on the example of a complete-change form of this example.

[0046] With reference to drawing 8 , by substrate processor 100A, the control electrode 31 is insulated from the processing container 11 by insulator layer 31A, and negative voltage source 31B is connected.

[0047] According to the configuration of drawing 8 , by controlling the potential of said control electrode 31 to suitable negative potential, it becomes possible to supplement with nitrogen ion N₂⁺ which has the positive charge excited in said plasma excitation space 11B, and it is avoided that nitrogen ion N₂⁺ invades into process space 11C.

[0048] In the substrate processor 100 of this example, or 100A, it is also possible by supplying helium gas, N₂ gas, and O₂ gas to said plasma gas supply-port 11p to perform acid nitriding treatment of said processed substrate 12.

[2nd example] drawing 9 shows the configuration of the substrate processor 200 by the 2nd example of this invention. However, the same reference mark is given to the part corresponding to the part explained previously among drawing 9 , and explanation is omitted.

[0049] With reference to drawing 9 , by this example, the shower plate 14 is removed, instead two or more raw gas inlet 11P are formed in said processing container 11 to the processed substrate 12 at the abbreviation symmetry target. Consequently, in this example, the cover plate 15 which constitutes a dielectric window is exposed in the upper part of said plasma excitation space 11B. Moreover, in said plasma excitation space 11B, the processing container side attachment wall is covered with quartz liner 11D like the previous example.

[0050] According to this example, it is possible by simplifying the configuration of the substrate processor 11, being efficient at cheap costs, supplying helium gas and N₂ gas to said plasma gas supply-port 11p, and supplying about 28GHz microwave to said radial line slot antenna 20 to perform nitriding treatment of the processed substrate 12 using atom-like nitrogen N*. Moreover, it is possible by supplying helium gas, N₂ gas, and O₂ gas to said plasma gas supply-port 11p to perform acid nitriding treatment of the processed substrate 12.

[3rd example] drawing 10 shows the configuration of the substrate processor 300 by the 3rd example of this invention. However, the same reference mark is given to the part corresponding to the part explained previously among drawing 10 , and explanation is omitted.

[0051] Although it has the substrate processor 1 which explained the substrate processor 300 by drawing 1 previously with reference to drawing 10 , and a similar configuration, the previous control electrode 31 and the same control electrode 6 are formed into the quartz processing container 2, and it is separated into plasma excitation space 2B1 by which high density plasma 2D is excited for the space in said

processing container 2, and process space 2B2 containing the processed substrate 4 by the control electrode 6.

[0052] In this example, helium gas and N₂ gas are introduced into said plasma excitation space 2B1 from said raw gas supply line 2C, and high density plasma 2D which has a high electron temperature and plasma energy which excite atom-like nitrogen N* in said plasma excitation space 2B1 is formed.

[0053] Thus, formed atom-like nitrogen N* is diffused in process space 2C through said control electrode 6, and nitrides the front face of the processed substrate 4. Even if the electron temperature and energy of the plasma are dramatically high in said plasma excitation space 2B1 also in this configuration, it falls to suitable level to process the processed substrate 4 in said process space 2B2.

[0054] Also in this example, by controlling the potential of said control electrode 6 by voltage source 6A, the cation of low energy, such as N₂⁺ produced in said plasma excitation space 2B1, is captured, and it becomes possible to eliminate from process space 2B2. Moreover, it becomes possible by controlling the potential of said control electrode 6 to control the condition of high density plasma 2D in said plasma excitation space 2B1.

[0055] In the substrate processor 200 of this example, it is also possible by introducing helium gas, N₂ gas, and O₂ gas from said raw gas supply line 2C to perform acid nitriding treatment of a substrate 4 in said process space 2B2.

[0056] As mentioned above, although this invention was explained about the desirable example, various deformation and modification are possible for this invention in the summary which it is not limited to this specific example and indicated to the claim.

[0057]

[Effect of the Invention] By using helium as plasma excitation gas according to this invention, it is possible to form the plasma which has sufficient high energy to excite atom-like nitrogen N* into a substrate processor, and it becomes possible to carry out nitriding treatment of the processed substrate efficiently by using atom-like nitrogen N* excited by doing in this way. In that case, by separating the plasma excitation space in which the high density plasma is formed with a control electrode from the process space where a processed substrate is contained, it becomes possible to reduce the plasma energy in process space to the suitable level for substrate processing, and it becomes possible to carry out the trap of the cation formed in plasma excitation space. When applying this invention to the substrate processor using the microwave excitation plasma, it can avoid that plasma energy becomes excessive by performing plasma excitation by the microwave of the frequency beyond about 28GHz or it.

[Translation done.]

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